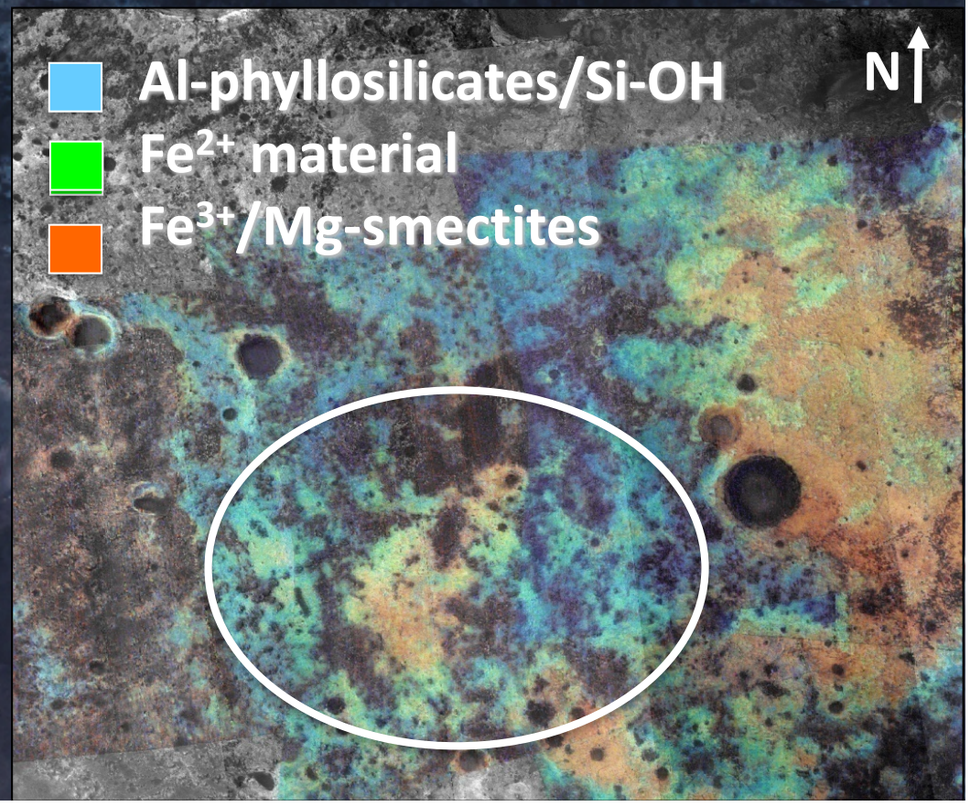
Mawrth Vallis: *Detailed Description of Mineralogy and Stratigraphy*

Janice Bishop
and Mawrth Vallis team



Mineralogy Highlights

- Thick phyllosilicate units throughout ellipse and surrounding region.
- Variety of aqueous alteration minerals: nontronite, Fe^{2+}/Mg-clays, sulfates, zeolites, opal, montmorillonite, kaolinite, allophane in ellipse and surrounding region.
- Mixtures of clays, gypsum, jarosite and alunite consistent with saline lakes.
- Several testable hypotheses.

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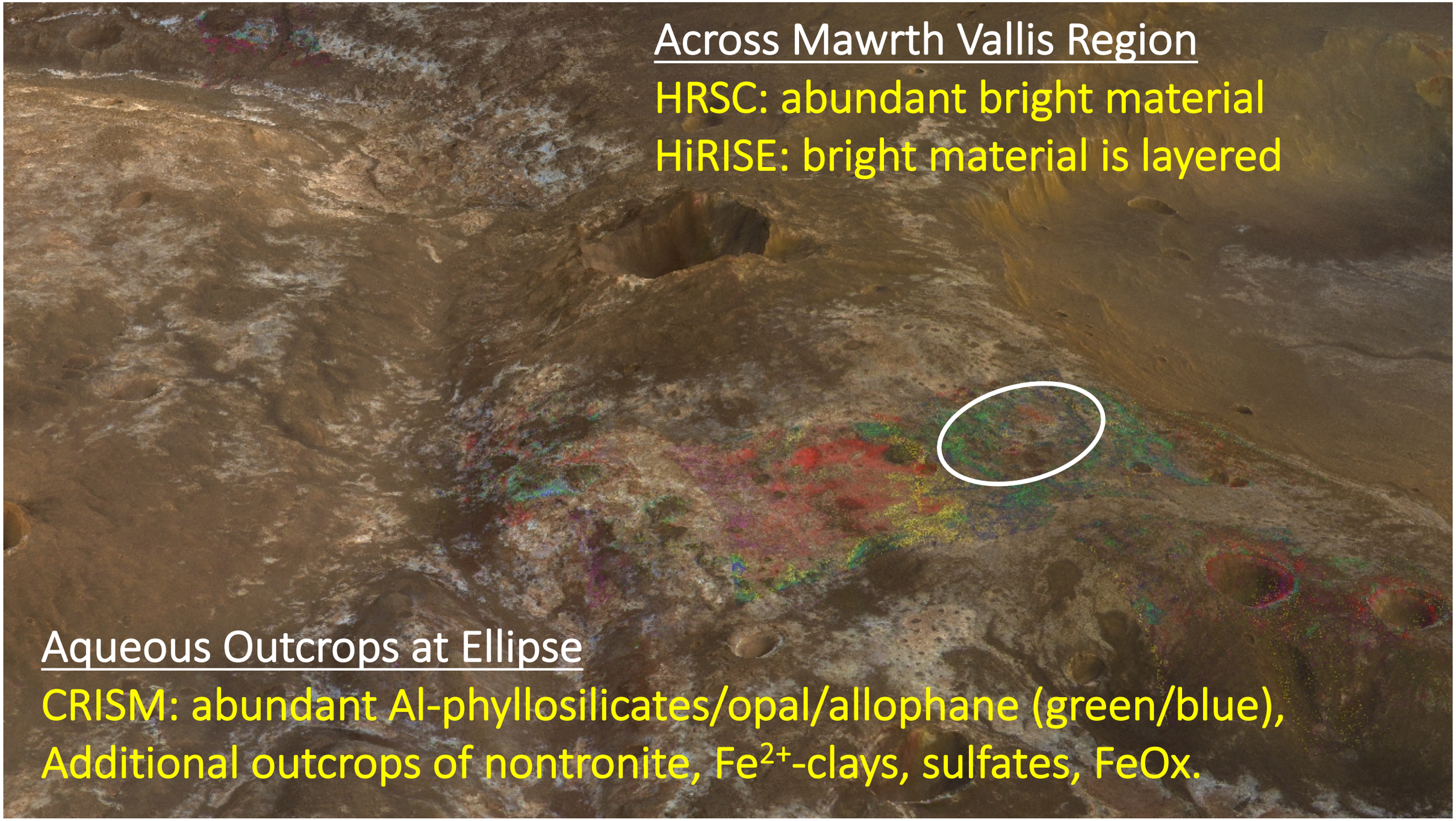
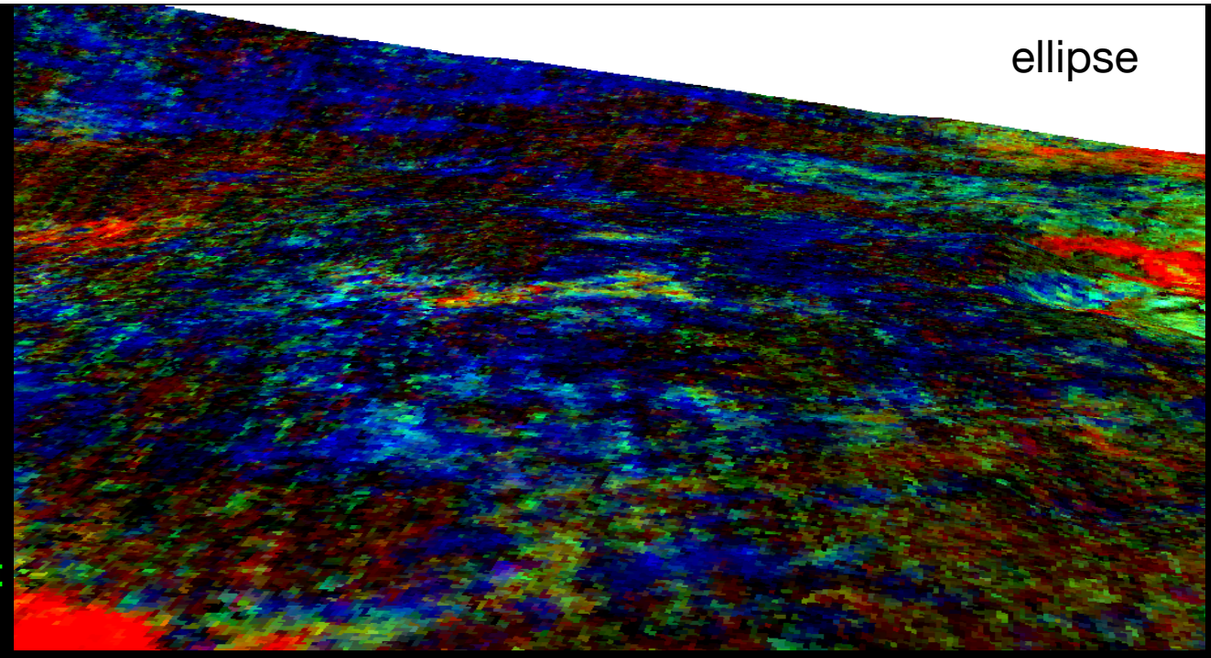

Across Mawrth Vallis Region
HRSC: abundant bright material
HiRISE: bright material is layered
Aqueous Outcrops at Ellipse
CRISM: abundant Al-phyllosilicates/opal/allophane (green/blue),
Additional outcrops of nontronite, Fe^{2+}-clays, sulfates, FeOx.

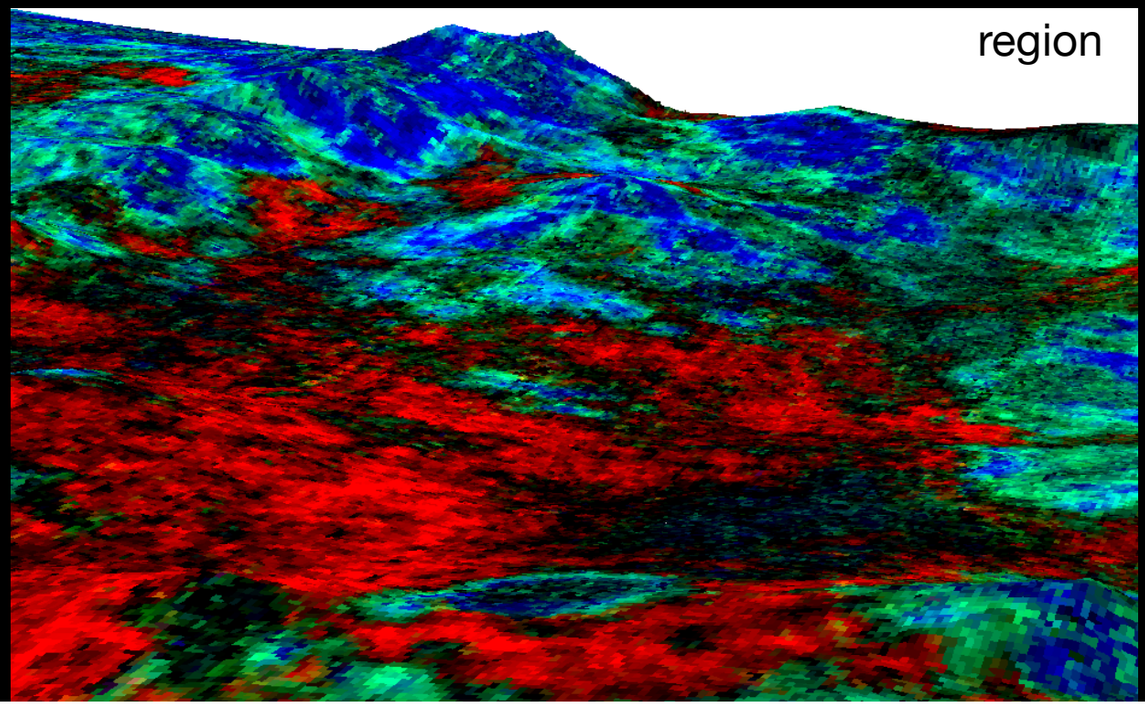
Stratigraphy at ellipse and in region

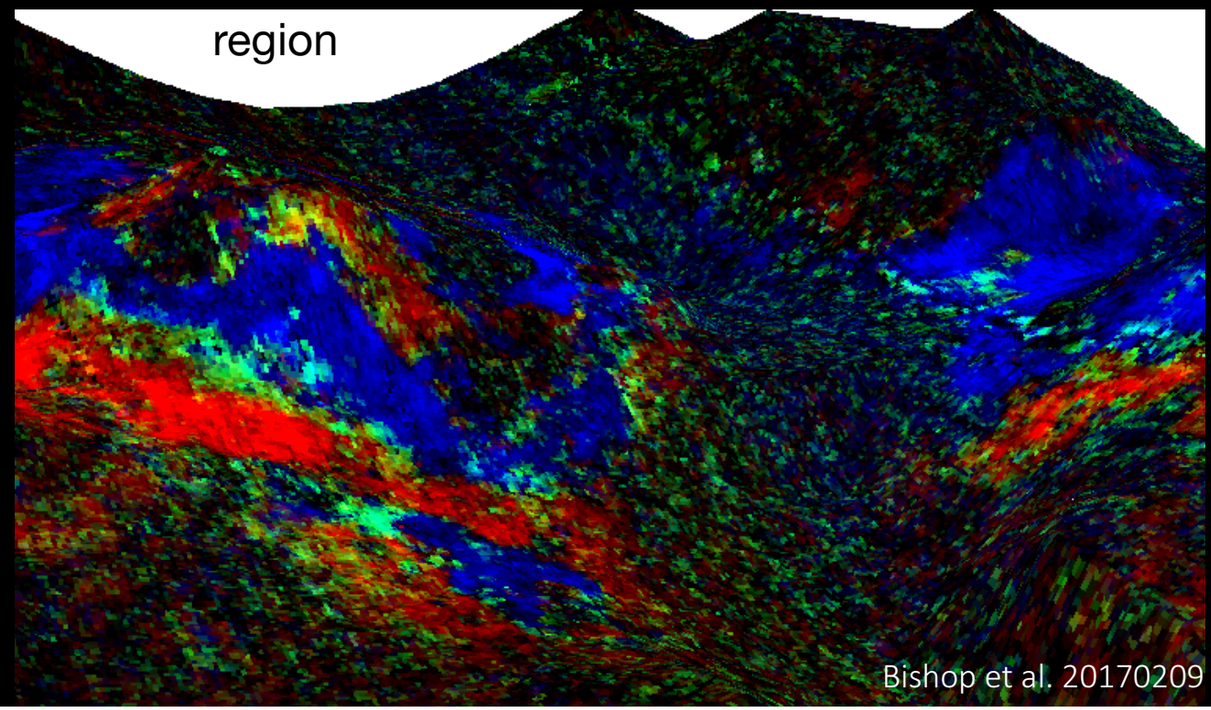
Anywhere we land, we will have multiple types of phyllosilicates & aqueous materials nearby!

CRISM MTR3 parameters
R=bd2290, G=min2250, B=bd2210
10X vertical

-upper Al/Si-OH units
-transition "doublet" unit
-Fe/Mg-smectite unit







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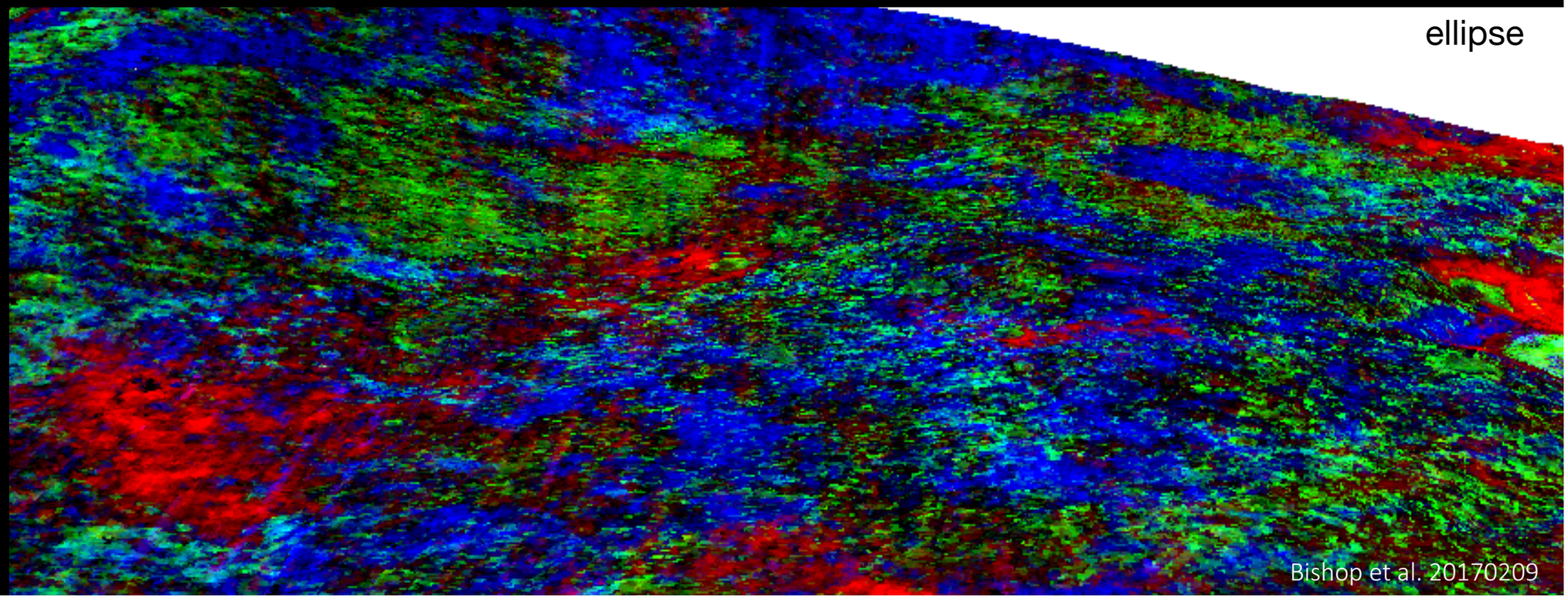
Stratigraphy at ellipse

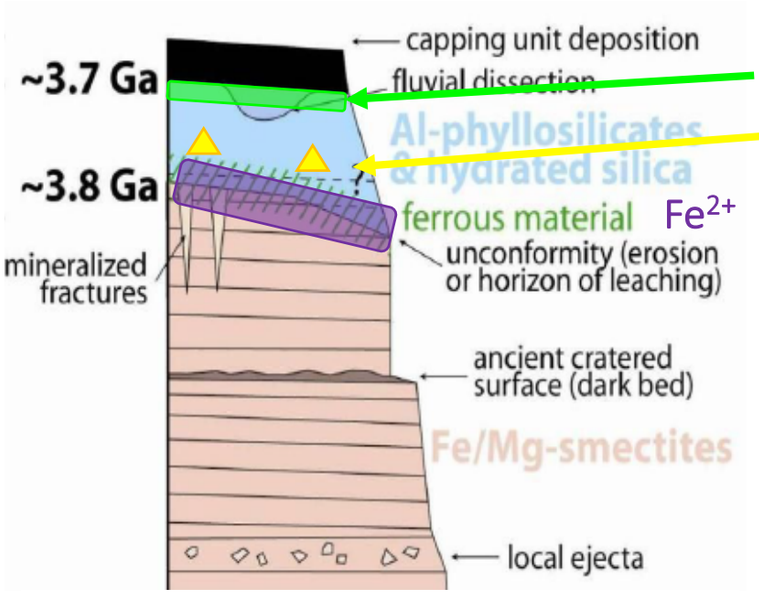
View of multiple types of phyllosilicates, aqueous materials and cap rock.

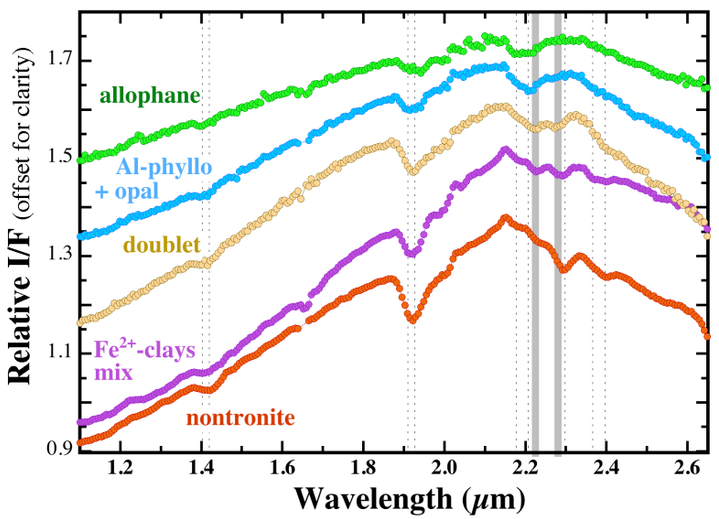
-upper Al/Si-OH units
-mafic matrial
-Fe/Mg-smectite unit

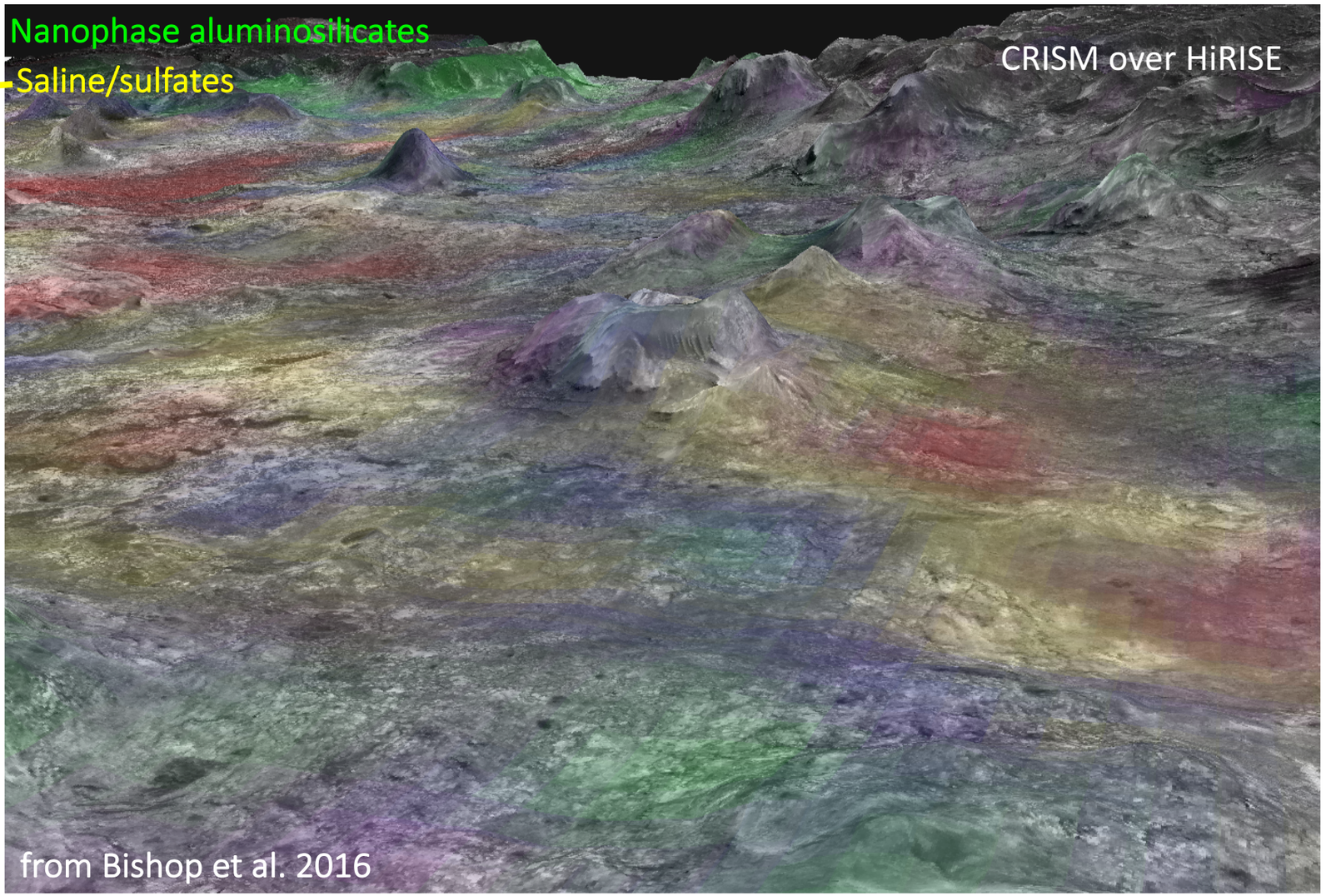


CRISM MTR3
R=bd2290,
G=bdi1000vis,
B=bd2210
20X vertical

Stratigraphy in parts of region, outside ellipse







Mawrth Vallis Mineralogy Suggests Multiple Aqueous Geochemical Environments

- Deposition of 150-200 m thick nontronite (Fe/Mg-smectite) unit during Noachian requiring high water/rock ratio environment.
  - -no evidence of thermal processing such as diagenesis.
  - -could be formed in surface or subsurface aqueous environment.
- Changing redox conditions to form ferrous clays on top of nontronite:
  - -reducing conditions?
  - -leaching?
- Neutral or mildly acidic conditions with high water/rock ratio environment (kaolinite, montmorillonite, opal).
  - -no evidence of thermal processing such as diagenesis.

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Mawrth Vallis Mineralogy Suggests Multiple Aqueous Geochemical Environments

- Saline environment:
  - -mixtures of clays and altered clays with small amounts of sulfate.
  - -isolated Ca-sulfates such as gypsum and basanite.
  - -isolated jarosite and alunite indicate localized low pH conditions.
- Upper unit spectrally different nanophase aluminosilicates (e.g. allophane and imogolite) indicates well-drained system and/or cold environment.
- Low water/rock ratio since allophane formed.

  (if warm water had returned, clays would have formed from allophane)

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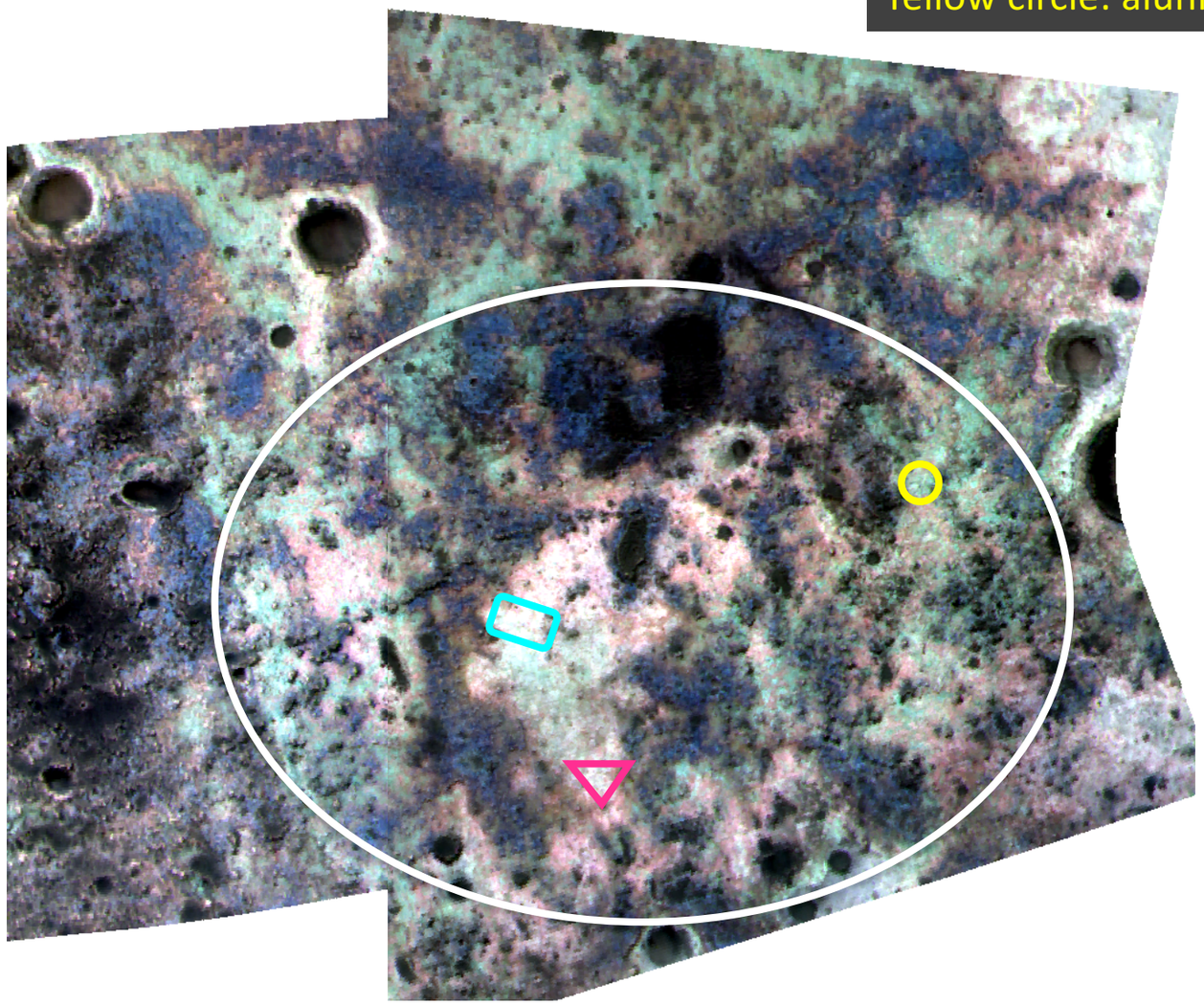
Mawrth Vallis Mineralogy Suggests Multiple Aqueous Geochemical Environments

- Phyllosilicate units emplaced in Noachian, erosion and fluvial alteration late Noachian.
- Multiple potential formation processes to be evaluated:
  - -clay deposits in sedimentary basin.
  - -in situ aqueous alteration of basaltic ash-fall.
  - -pedogenesis in moist climate.
  - -aqueous transport of sediments.
  - -hydrothermal alteration.
- Igneous processes at caprock
  - -accessible in ellipse.

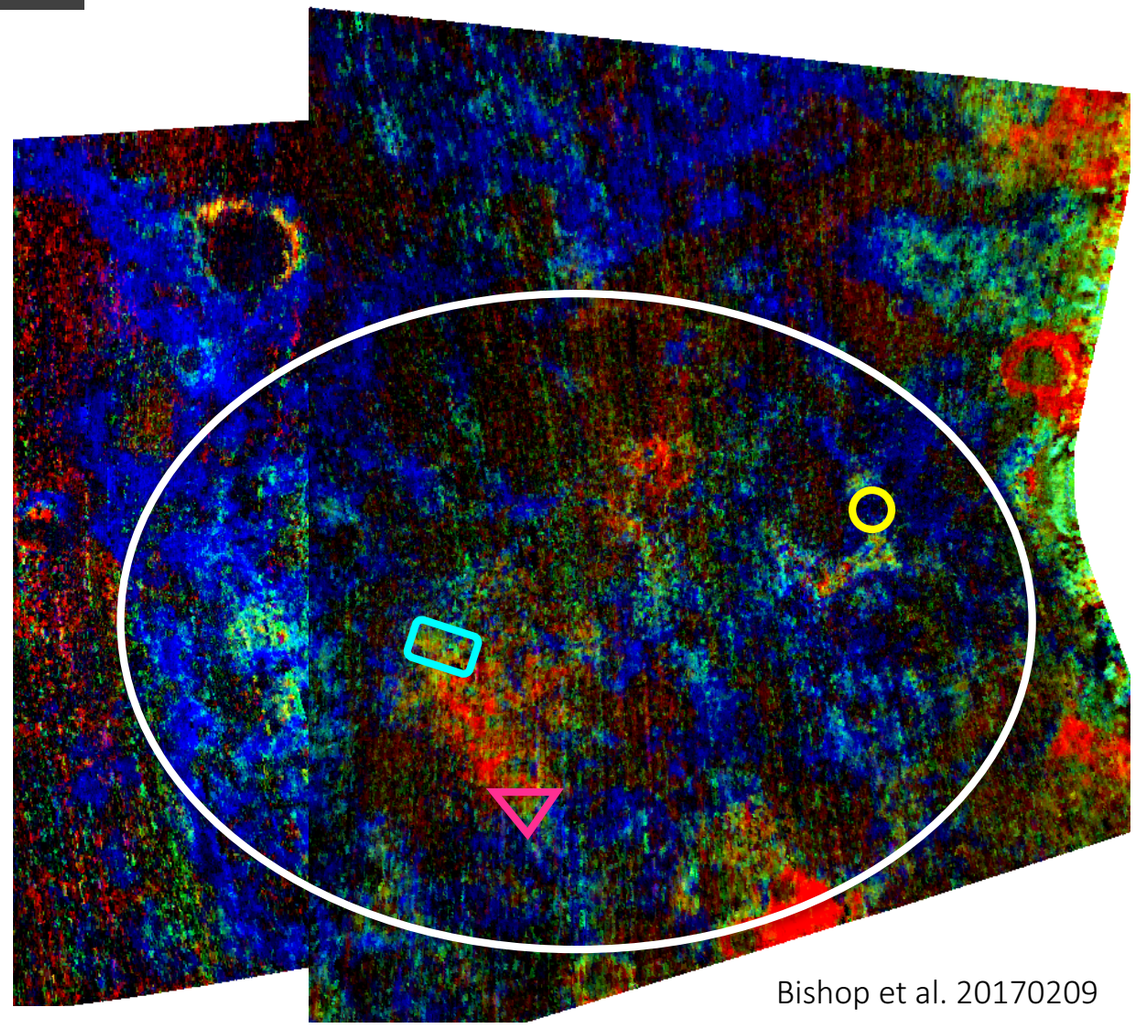
Ellipse

FRT0000B141, FRT0000BB59
(default parameters)

Blue box: gypsum?
Pink triangle: jarosite
Yellow circle: alunite?



FRT0000B141, FRT0000BB59
-upper Al/Si-OH units
-transition unit (sulfate/doublet)
-nontronite unit



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Ellipse

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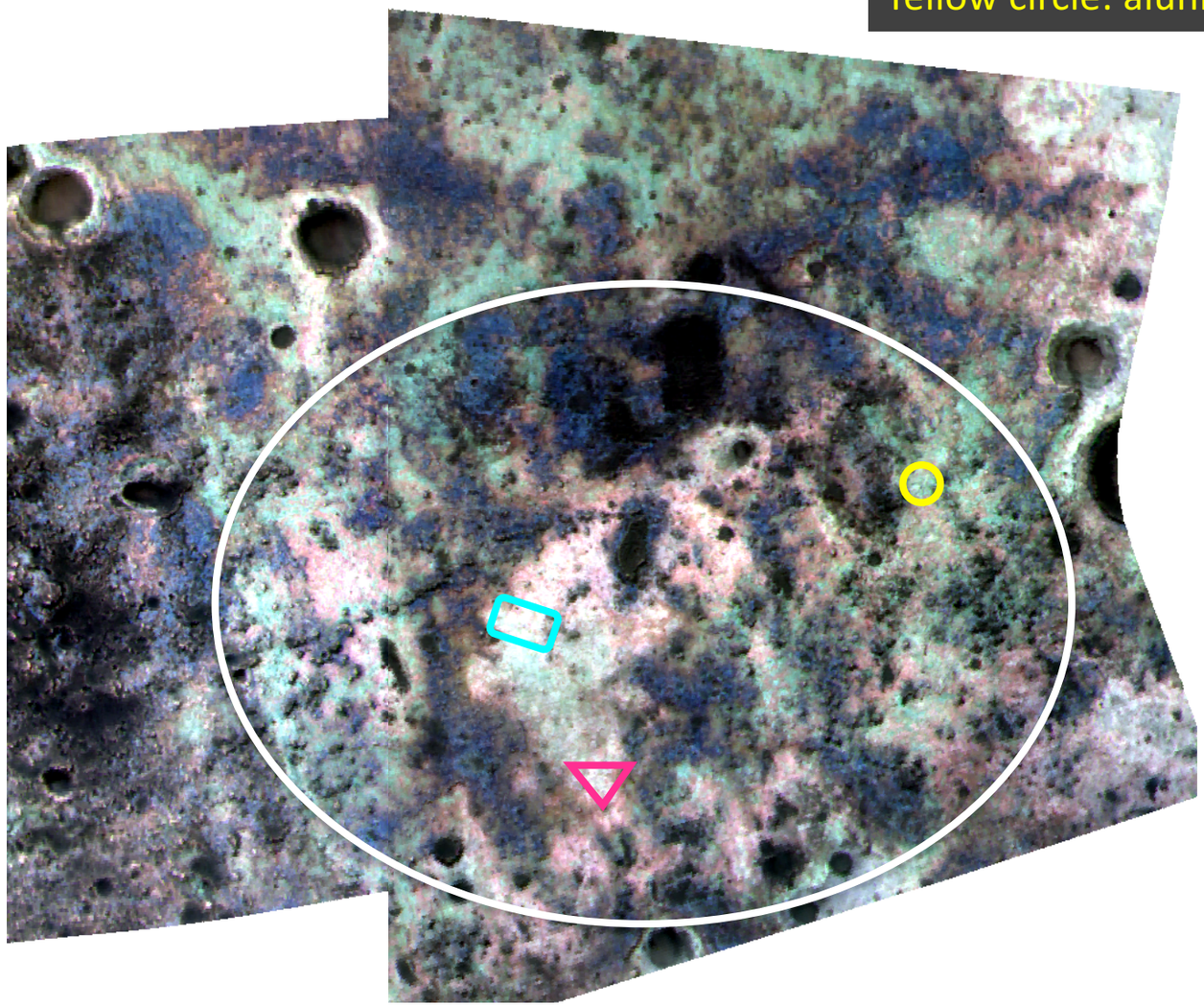
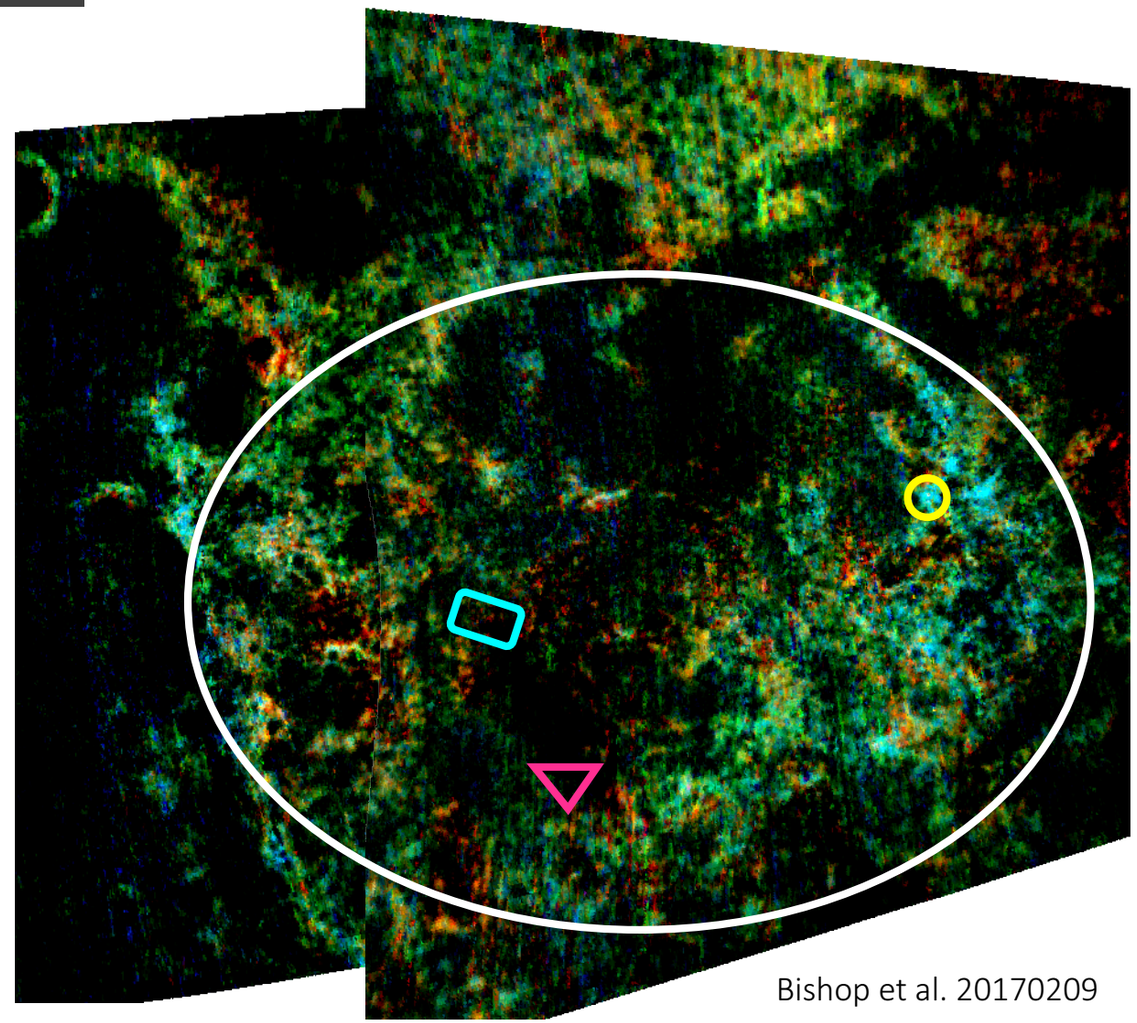


FRT0000B141 , FRT0000BB59
PAL parameters
-montmorillonite/opal
-alunite?
-kaolinite (white/pale yellow)



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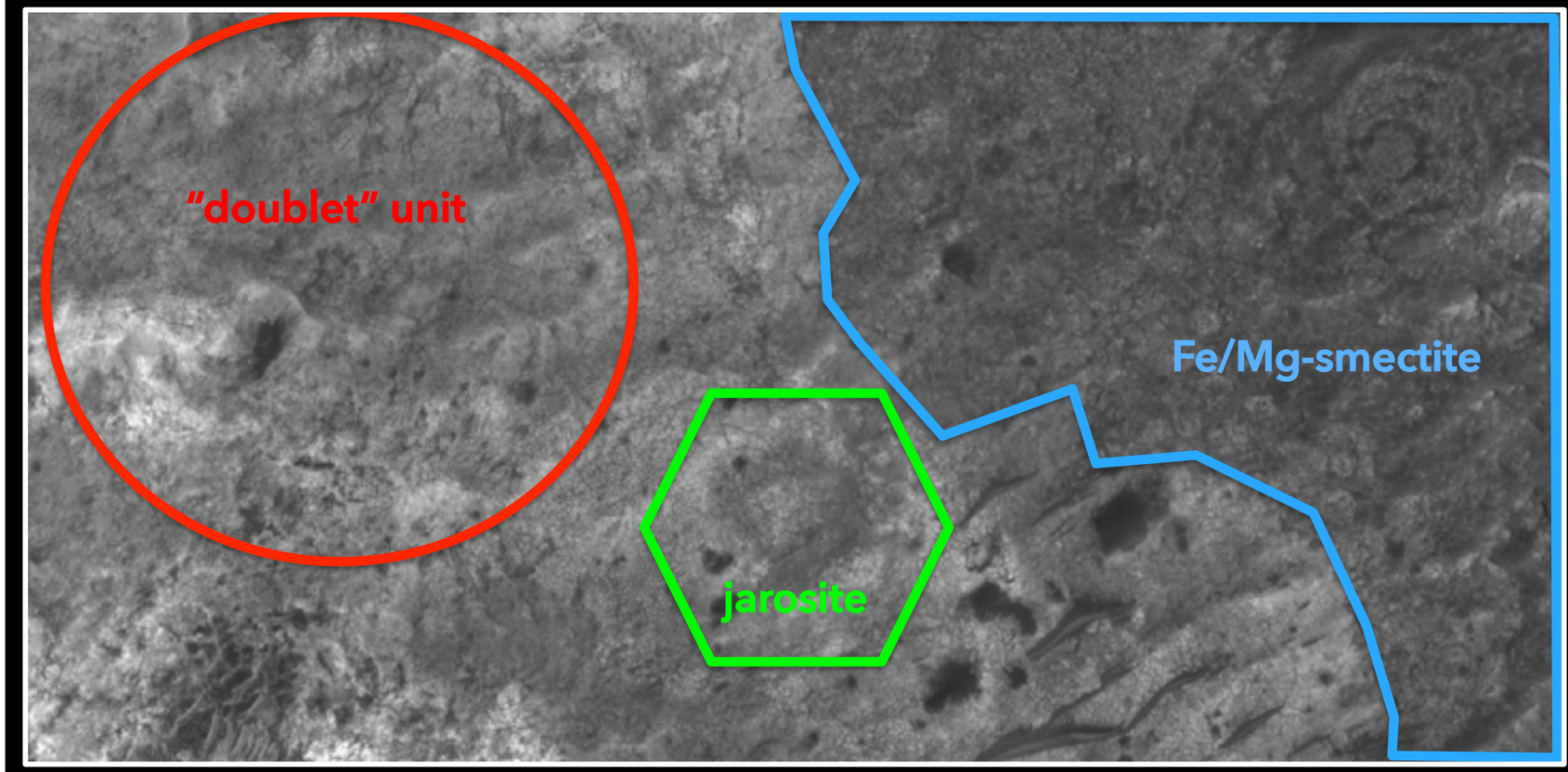
Outside ellipse: spatial relationship between nontronite, jarosite, other sulfates and altered clays



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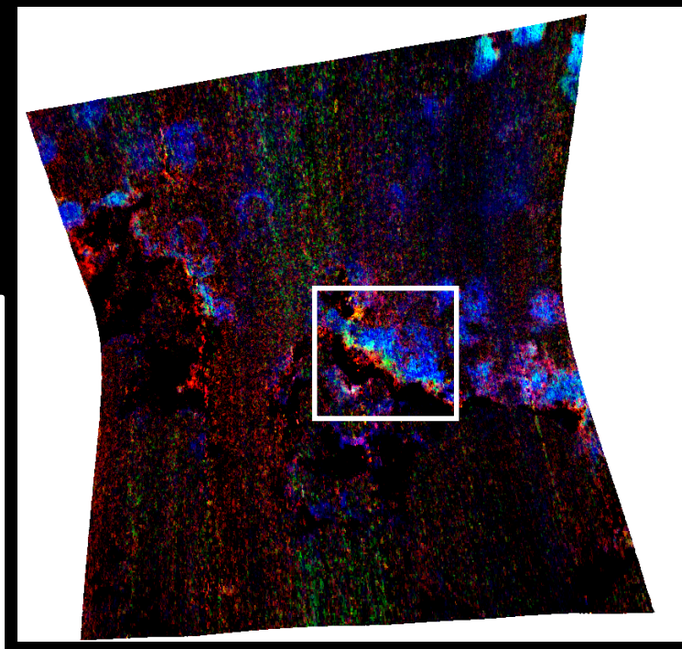

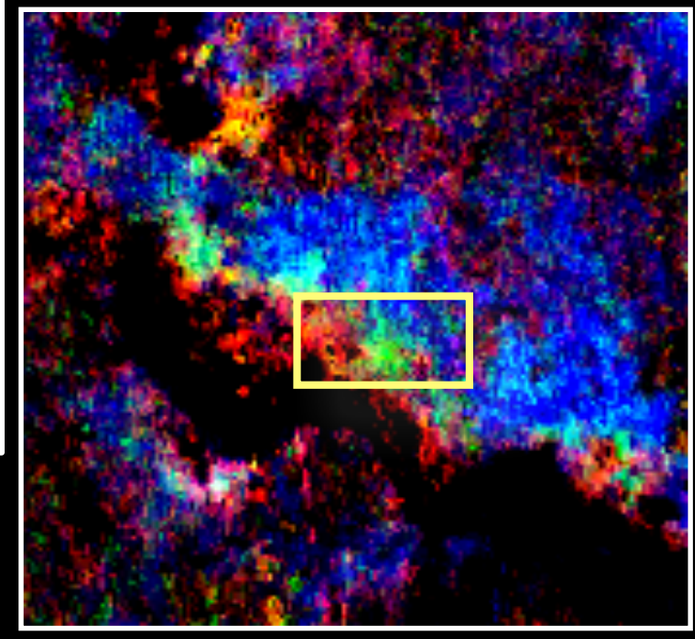

Rmin2250_Gbd2265_Bbd2290

FRT00003BFB

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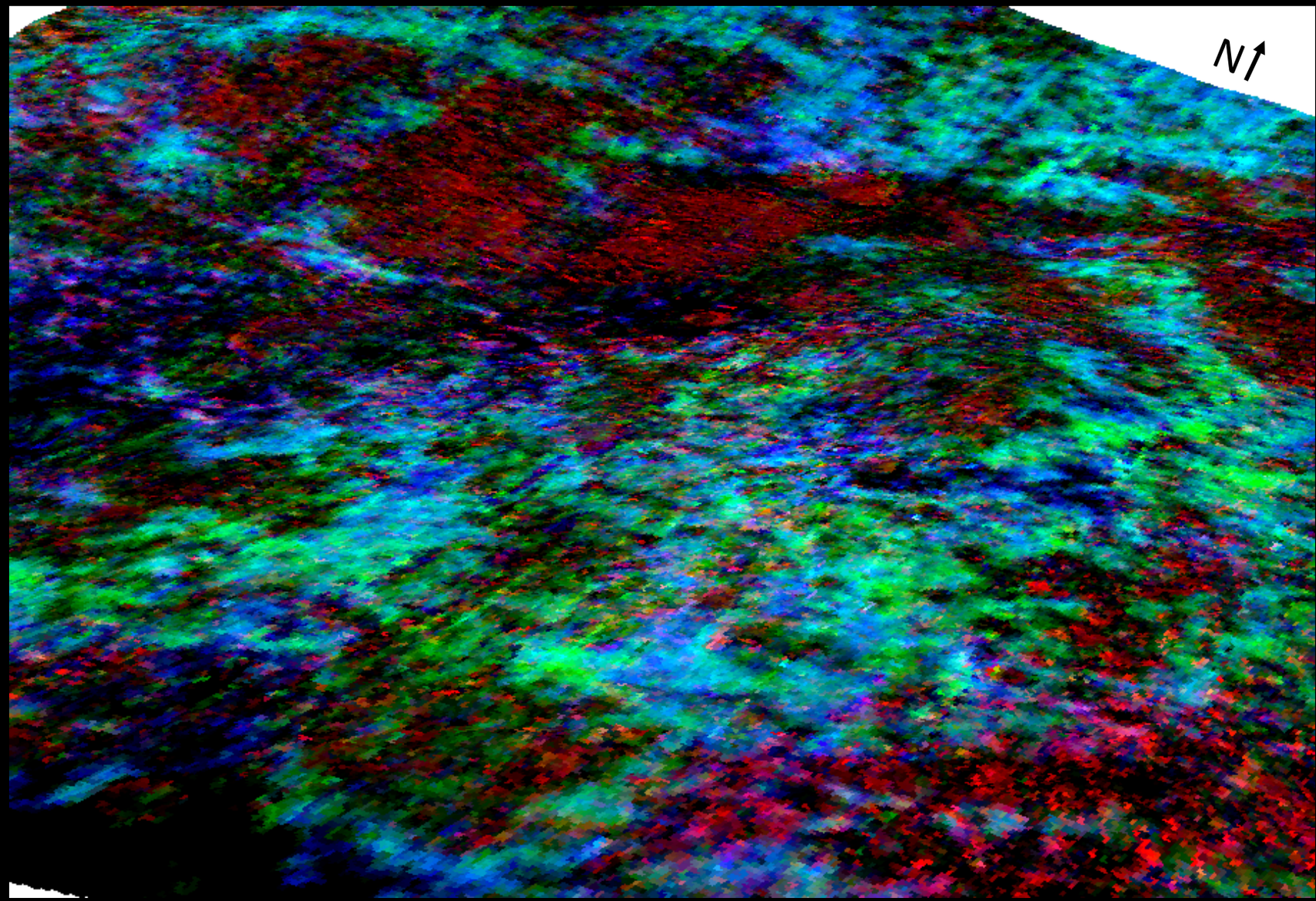
Spatial relationship between upper units

Unaltered Caprock

Nanophase aluminosilicates (e.g. allophane)

Al-phyllosilicates (montmorillonite, kaolinite), opal

FRT0000B141
R = BDI1000VIS
G = bd2190
B = bd2210



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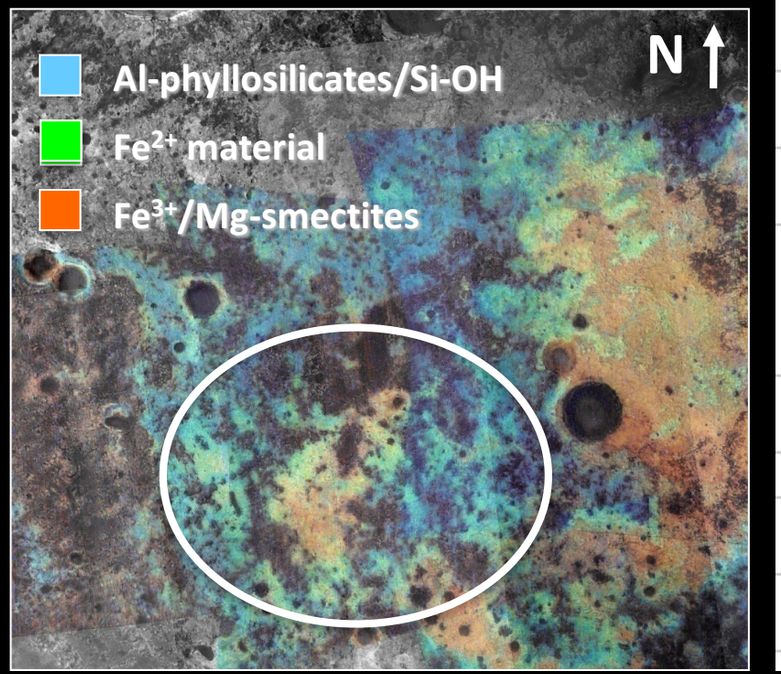
Summary of Minerals at Mawrth Vallis



Regional mineralogy	Minerals in ellipse
Fe3+/Mg-smectites	Fe3+/Mg-smectites
Al-phyllosilicates (kaolinite, montmorillonite)	Al-phyllosilicates (kaolinite, montmorillonite)
Fe2+/Mg-clays	Fe2+/Mg-clays
Hydrated silica	Hydrated silica
Allophane	Allophane
Ferrihydrite/FeOx	Ferrihydrite/FeOx
Sulfates (basanite, jarosite, alunite)	Sulfates
Zeolites	Zeolites?
Pyroxene	Pyroxene
Plagioclase	Plagioclase

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Hypotheses to be Tested at Mawrth Vallis

- Redox transition:
  1) did this form by a reducing agent that reduced the Fe in the nontronite unit?
  2) did this form due to trapped organics that provided a reducing environment for new sediments?
  3) did leaching of Fe^{2+} from subsequent ash get trapped at the nontronite boundary?

- Formation of nontronite-rich unit:
  1) could the expansive nontronite unit have formed in a subsurface environment?
  2) or was this formed in a sedimentary environment? (evaluate layering)

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Hypotheses to be Tested at Mawrth Vallis

- Formation of phyllosilicate-rich stratigraphy:
  1) Clay deposits in sedimentary basin?
  2) Pedogenesis in moist climate?
  3) In situ aqueous alteration of basaltic ash-fall?
  4) Aqueous transport of sediments?
  5) Hydrothermal alteration?
- Mixed unit containing clays, gypsum and jarosite:
  1) is this the result of a saline lake?
  2) or could there be acid alteration of the nontronite?
  3) or are there fine-scale distinct outcrops of these components that are just mixed when viewed from orbit?

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Implications from Mineralogy at Mawrth Vallis

- Thick phyllosilicate units dated to Noachian period.
- Similar vertical stratigraphy across 100s (or 1000s) km implies regional aqueous processes. We can access this in ellipse.
- Mineralogy shows multiple aqueous geochemical environments through time and small regional variations due to localized processes (e.g. ponds, evaporites).
- Allophane and imogolite at top of vertical clay profile indicate the final change in climate: Low water/rock ratio or cold water similar to Antarctic Dry Valleys.
- Unaltered caprock provides access to igneous material.

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Implications from Mineralogy at Mawrth Vallis

- Anywhere we land, we will have phyllosilicates nearby.
- Modeling indicates highest abundances of phyllosilicates at Mawrth Vallis.
- Several different types of habitats supported by mineralogy: subsurface, subaqueous, subaerial, and Fe-rich.
- Redox interface between Fe^{3+} in nontronite and Fe^{2+} in Fe/Mg-clays could provide a microbial habitat.
- Several lithologic boundaries between distinct clay-bearing units could provide a microbial habitat.
- Phyllosilicates, silica and allophane excellent for preserving biosignatures.

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Conclusions from Mineralogy at Mawrth Vallis

- Mars space exploration has demonstrated that Martian geology and environment evolved dramatically during the first few hundred million years. This is recorded in the mineralogical diversity placed in geomorphological context.

  -visiting Mawrth Vallis will enable exploring this critical Noachian time period.

- It is remarkable that Mars has uniquely preserved sites with records of ancient rocks. Investigating these is essential for determining if habitable sites were actually inhabited.

  - overarching goals of Mars2020 include characterizing potential habitable sites and searching for potential bio-relics.

  -visiting Mawrth Vallis will enable investigating these likely habitable sites.

- Marwth Vallis is packed with thick outcrops of phyllosilicates, a variety of aqueous materials, and pristine igneous cap rock throughout the ellipse.

  -landing at Mawrth Vallis will guarantee finding a full range of minerals and exciting geological features that will enable tracing the evolution of Mars' ancient environment and climate.

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